

Application of Earned Value Based Metrics to Enhance the Performance Measurement of Engineering Project Management

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Abstract

Earned value management (EVM) includes cost control and considers resource planning and management techniques for schedule and technical performance. The present study aims to show the theoretical and practical dimension of performance measurement on a small-scale construction project using the earned value methodology, and thereby contribute to its wider practical application. In addition, the usage of the correlation between the schedule performance index and cost performance index and the meaning of indices such as budgeted cost of work scheduled, budget cost of work performed, and the actual cost of work performed is illustrated in detail to analyze the performance of EVM application in the project management.

Keywords: Earned value management, Engineering project, Project management, Scheduling, Performance index.

Mühendislik Proje Yönetiminin Performans Ölçümünü Geliştirmek İçin Kazanılan Değer Esasına Dayalı Ölçütlerin Uygulanması

Öz

Kazanılmış değer yönetimi (KDY) projelerin maliyet kontrolü, zaman planlaması ve teknik performansı için kaynak planlaması ve yönetim tekniklerini içermektedir. Bu çalışma, kazanılmış değer yöntemi metodolojisini kullanarak küçük ölçekli bir inşaat projesinde performans ölçümünün teorik ve pratik boyutunu göstermeyi ve böylece daha geniş bir pratik uygulamaya katkıda bulunmayı amaçlamaktadır. Ayrıca, zaman performans indeksi ile maliyet performans indeksi arasındaki ilişkinin kullanımı ve planlanan işin bütçelenmiş maliyeti, gerçekleştirilen işin bütçe maliyeti gibi endekslerin anlamı, proje yönetiminde KDY uygulaması ile proje performansının analiz edilmesinde ayrıntılı olarak gösterilmektedir.

Anahtar Kelimeler: Kazanılan değer yönetimi, Mühendislik projesi, Proje yönetimi, Çizelgeleme, Performans endeksi.

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1. Introduction

The basic goal of project planning is to effectively carry out entire project needs to guarantee completion on budget and on timely [1]. In this, the S-curve, which plots cost versus time, assures a scale of schedule performance. Irrespective of how meticulously the project schedule plan was built up, the evaluating the project continuation and efficiency of work done, also success of the overall construction project, without timely and continuous performance supervision is not easy task [2]. Selecting the convenient tracking methodology is one of the most tedious jobs in construction project field. Actually, plenty of construction projects teams just uses the actual costs comparison with the planned costs in worldwide. But the shortcoming of this approach arises from not considering the value of the work done, which removes the costs consideration: the earned value of the work. [3]. The monitoring methodology that facilitates the combination of the planned amount of work with what has been fulfilled in reality, to identify if cost, schedule, and work done are running as per the planned schedule and quantification of work progress of project regular performance is Earned Value Management (EVM).

Kim et al. discussed the earned value usage for different sorts of construction sectors as well as projects [4]. Moreover, Vandevoorde and Vanhoucke prompted that the topmost trustworthy approach to forecasting time in fruition is the earned schedule technique [5]. Lipke et al. is presented an assured determining system of the total project cost and time span on enhance the potential of project managers to making educated choices [6]. Aceves et al. recommended a graphical structure to EVM should consolidate the measurements from claiming venture expense and plan for management of risk [7]. Czemplik applied EVM to progress supervision of construction projects [8]. The essential idea of earned value might have been concentrated starting with those industrial engineering approaches, which to point of interest investigated “cost-performance” methodology. In the transform about cost-performance evaluation, those comparability about wanted and genuine qualities of values furthermore expense might have been attained. In course of time span, the utilization of this system was not restricted just on state industrial also military undertakings but is for all that moderately unwell exerted to trading and exclusive projects [9]. The value of the EVM is that it meets a precise dimension of the cost and time yield in the guiding of project tracking as well as supervision. Christensen and his colleagues in time span of 1998-2002 carried out a scientific study and expressed that the cost performance index determiner obtained at the 15-20% of project ending, ensures a substantially trustworthy scale for forecasting of total project cost with a maximum error of $\pm 10\%$ [10].

Moslemi-Naeni et al. indicated another fuzzy-based earned value instance with the benefit of rising and examining the earned value indices and the time and the cost estimates toward fruition under questionable matter [11]. Pajares et al. presented two new measurements to coordinating EVM with management of hazard methodologies: cost control also schedule control indices. These two indices crosscheck EVM scales with the most extreme value that a project should demonstrate if the project might have been running under the risk dissection theory. [12]. in this respect, EVM may create a tool of early warning system during exactly 20% of project finishing. Though, the EVM utilization in the construction sector is even so at the falling standard. One of the most prevalent challenge in the provision of EVM procedure that professionals state contain: the inevitability of elaborate layout prior to the project launch, dependable performance scale and remarking, hurdles in measuring actual physical advancement

of construction activities, and accurate input data [13]. Hence, the option of correct configuration and its citation to follow up and supervise of a particular project is the main factor of successful EVM application. The remaining of study is arranged as follows: The significance of the construction project correlated with the Earned value management which includes the basic concepts is presented first. To show the EVM efficiency in practical projects, a small instance problem is then demonstrated and finally, detailed discussion and conclusion are provided, respectively.

2. Earned Value Management: Basic Concepts

Earned value management (EVM) combines a project's domain, schedule, under a bound together situated metrics to monitor and forecast the project's performance. Fabricating pieces about the greater part EVM measurements would the following three components. [9]:

- Earned value (EV) or budgeted cost of work performed (BCWP): it is the budgeted amount for the work actually accomplished on the schedule activity or work breakdown structure (WBS) component during a given time span. It is obtaining by multiplying the percent completed by the budget amount for the work or by review and updating of a project.
- Planned value (PV) or budgeted cost of work scheduled (BCWS): it is the budgeted cost for the work scheduled to be completed on an activity or WBS component in a particular time. It is obtained from the cash flow diagram. The S-curve for a project represents the BCWS.
- Actual cost (AC) or actual cost of work performed (ACWP): It is the total cost originated in accomplishing work on the schedule activity or WBS component just at a specific time. It is resolved from accounting records or the responsible party that keeps record of actual expenditure money, that means it is secret and actual money spent by the contractor.
- Estimate to Complete (ETC): the expected extra cost necessary to finish the project.
- Estimate at Completion (EAC): The expected total cost of the project when the defined scope of work is completed.
- Budget at Completion (BAC): The total approved budget when the scope of the project is completed (including any project contingencies).

To analyze the present status of a project and estimate its future probability, the following data points can be utilized. EVM analysis has two parts: cost analysis and schedule analysis. In schedule analysis, EVM uses both schedule variance ($SV = EV - PV$) and schedule performance index ($SPI = EV/PV$). Also, cost variance ($CV = AC - PV$) and cost performance index ($CPI = AC/PV$) are used in cost analysis of the EVM. Whenever $CV < 0$ and $CPI < 1$, the project is over budgeted (otherwise, if $CV > 0$ and $CPI > 1$ the project is under budgeted). Furthermore, if $SV < 0$ and $SPI < 1$, the project is delayed (otherwise, if $SV > 0$ and $SPI > 1$ the project is ahead of schedule). When $CV = 0$ ($CPI = 1$) and/or $SV = 0$ ($SPI = 1$) the project is respectively on cost and /or timely. The graph shown in Fig. 1 is a beneficial means for the project manager to supervise project efficiency depending upon advancement reports depending on interpretations of CPI and SPI data. By a method for following the development about these indices through those project's existence cycle, managers could identify deviations from arranging along these lines that they could make initial restorative actions. An exemplary of an ideal format to outline level reporting to management is demonstrated in Fig 2.

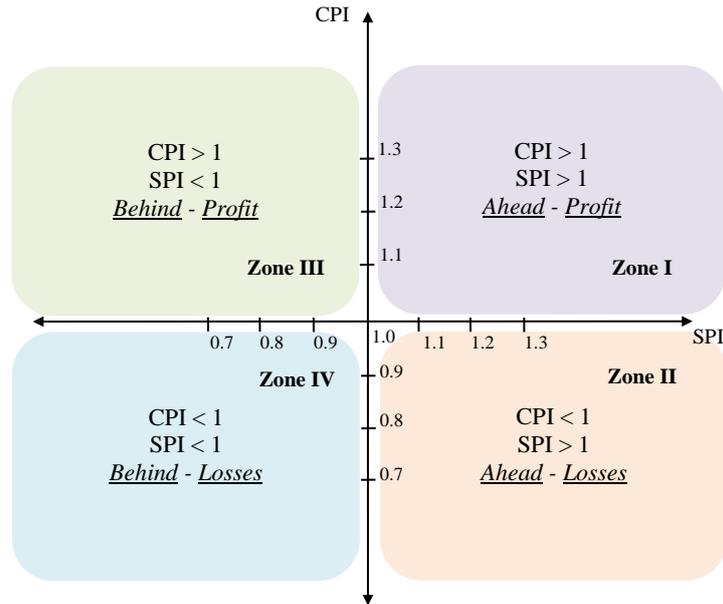


Figure 1. SPI and CPI Analysis Matrix of a Project

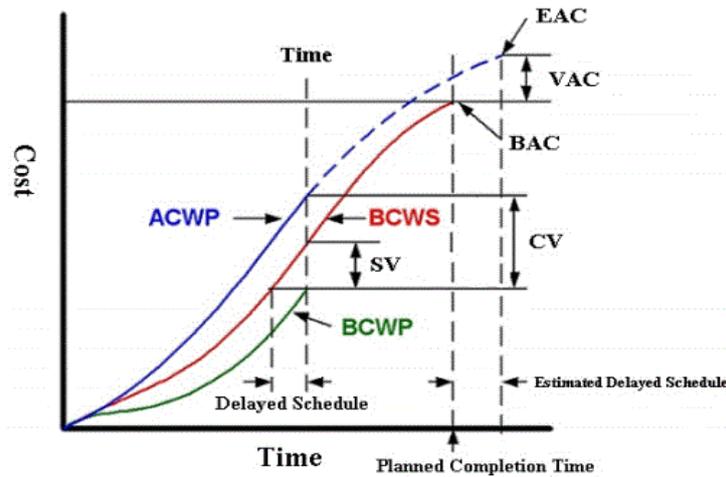


Figure 2. EVM Chart (Source: Chou, 2003)

3. Example Problem

The details of the review of a project on the 6th, 10th and 14th month is detailed below in Table 1. The originally budget value of the project is 36.441.086, 00 TL. Earned value analysis is performed at the given scheduled durations using following indices as well as graphical indications.

Table 1. Represents The Status Report Of The Project

BAC		36.441.086,00 TL	
MONTH	BCWS (Planned)	BCWP (Earned)	ACWP (Actual)
6	2.603.175,00 TL	2.140.309,50 TL	2.312.028,54 TL
10	27.582.743,00	32.143.413,85	30.526.798,00
14	34.236.708,00	33.093.821,00	31.939.468,00

4. Results and Discussion

Using the data in Table 1, indices, estimate to complete and estimate at completion are obtained and plotting the graphs, relevant comments are stated.

Table 2. Obtained Values Of Status Report Of The Project

VARIANCE		Indices		Forecasting		Variance
CV	SV	CPI	SPI	ETC	EAC	BAC
-171.719,0	-462.866,0	0.92573	0.82219	3.705.2760,534	39.364.788,534	36.441.086,000
161.661,50	456.067,00	1.05296	1.16535	4.081.526,611	34.608.324,611	36.441.086,00
115.435,30	-114.288,7	1.03614	0.96662	3.230.508.298	35.169.976,298	36.441.086,00

*CV=BCWP – ACWP, SV=BCWP – BCWS, CPI=BCWP/ACWP, SPI=BCWP/BCWS, ETC=(BAC-BCWP) / CPI, EAC=ACWP+ETC

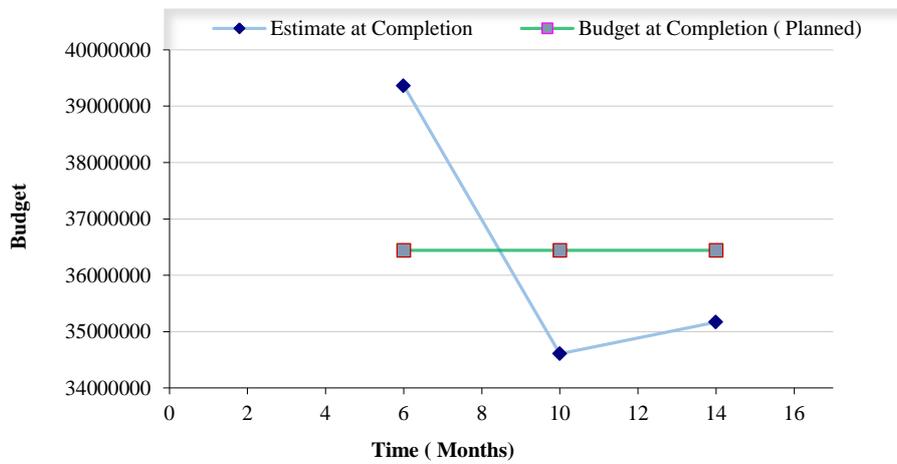


Figure 3. Planned vs estimated values

Dependent upon the analysis of the status report and graphical indication in Fig 3, the estimated cost of the project at completion for the 6th month of the updating (after 40% of the project execution) is 39.364.788, 534TL which is 2.923.702, 534 TL over the original budget of 36.441.086, 00TL. The project is projected to have a significant cost overrun.

Similarly the analysis of the status report and graphical indication reveals that the estimated cost of the project at completion for the 10th month of the updating is 34.608.324, 611TL which is 1.832.764, 4TL under the original budget of 36.441.086, 00TL. The cost performance is substantially better in proportion to the preceding status report.

Also the analysis of the status report and graphical indication represents that the estimated cost of the project at completion for the 14th month of the updating is 35.169.976, 298TL which is 1.271.110, 00 TL under the original budget of 36.441.086, 00TL.

Depending upon the analysis of the status report and graphical indication of Fig. 4 and 5 which are associated each other, the earned value of the project for the 6th month of the updating reveals that both the CV (Cost variance) and SV (Schedule variance) are smaller than zero which describes that the project is behind the schedule and making losses or over budget. In case of 10th month updating both the CV (Cost variance) and SV (Schedule variance) are greater than zero which indicates that the project is

ahead of the schedule and making profit or under budget. But again on the 14th month updating of the earned value, the CV is greater than zero and SV is smaller than zero which represents that the project is making profit since it is behind schedule.

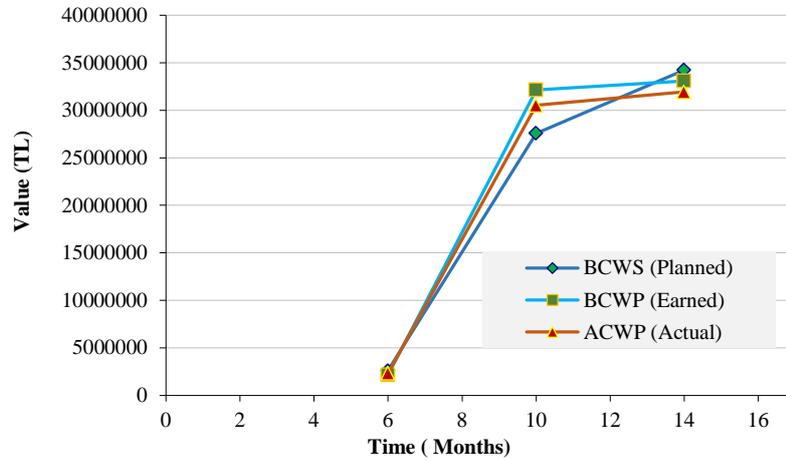


Figure 4. Graphical representation of BCWS, BCWP and ACWP values

By analyzing the graphical representation of CPI and SPI indices in Fig 6, the following comments can be stated.

- Review of the project on the 6th month:

According to the graphical interpretations of Fig 6, CPI and SPI both are less than 1.0, $CPI < 1$ implies a weak cost performance. That earned value is short of what the real costs for this reporting period. Cost performance index (CPI) equipoise between 0.925-0.93, which as a rule has a tendency to integrity because of extra endeavors to get done the project on time. Also in case of $SPI < 1.0$, the schedule performance is considerably worse than planned and lagging back the schedule.

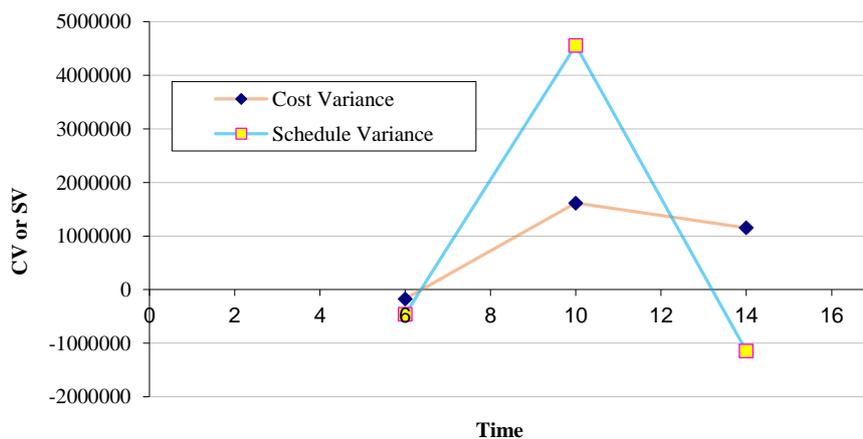


Figure 5. Variation of CV and SV

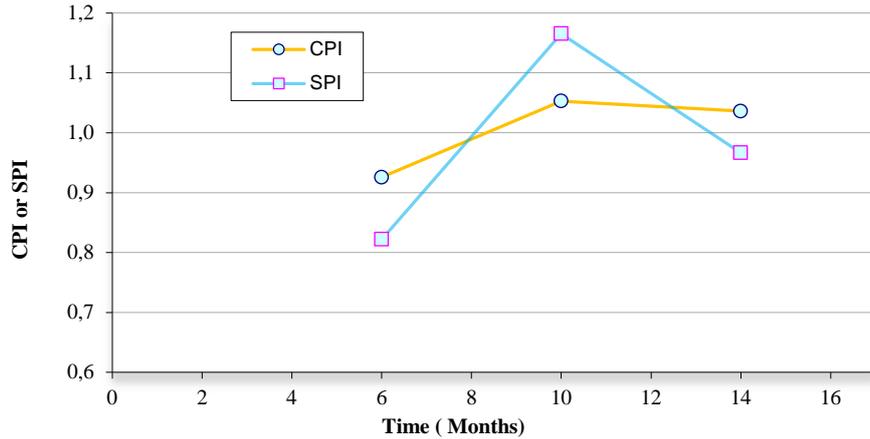


Figure 6. Graphical representation of CPI and SPI index

- Review of the project on the 10th month:

In this case values of CPI and SPI that are greater than 1.0 represent good project performance.

The SPI is greater than 1.0, which defines the schedule performance is carrying on better than planned. The project is ahead of schedule, which is a bit better than the previous status report and CPI > 1 the project is under budgeted.

- Review of the project on the 14th month:

CPI is greater than 1.0 and SPI is less than 1.0, which shows the cost performance is proceeding well and the project is under budgeted, but schedule performance is slightly worse and the project is lagging back the schedule, which points out the project will be completed fairly after than planned.

As per the graphical representation of CPI and SPI in Fig7. The following comments can be stated.

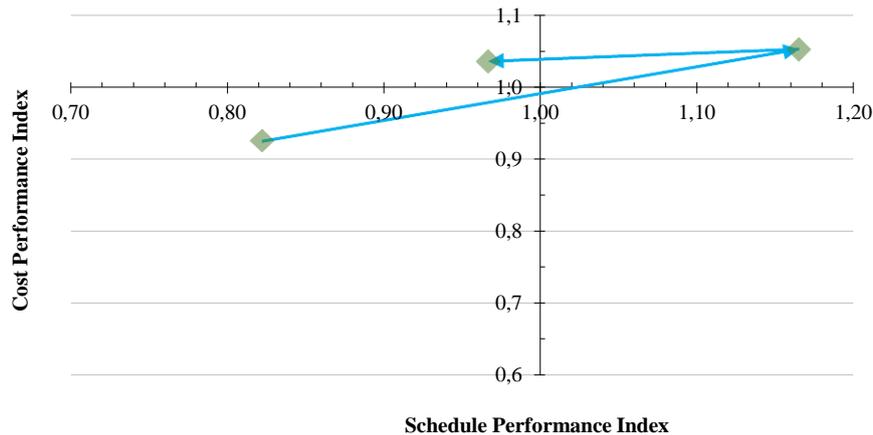


Figure 7. Graphical representation of CPI and SPI index

- Updating the project on the 6th month indicates that both CPI and SPI indices are located in **Zone III** which is (Behind Schedule – over budgeted).

- Review of the project on the 10th month shows that both CPI and SPI indices are located in **Zone I** which is ahead of schedule and under budgeted.
- Review of the project on the 14th month indicates that both CPI and SPI indices are located in **Zone II** which is behind the schedule and under budgeted.
- CPI demonstrates the usage of cost estimation in expenditure percentage form on certain days. A CPI value bigger than 1 indicates that outgoings are higher than work efficiency rate. Furthermore, CPI variance should not pass over 10%. Therefore, CPI is an influential index in making the decision providing project targets can be successfully reached.
- SPI shows work done output in the form of work acquisition ratio on particular days. SPI is a highly valid index for detecting and comparing schedule difficulty. An SPI value greater than 1 defines that the current output value has obtained the estimated efficiency value of a typical day in the future, which proposes favorable performing efficiency. Conversely, an SPI value less than 1 describes weak implementation output.

5. Conclusions

In this study, project managers were asked to concentrate management decisions on handling progress and cost budgets. The project exceeded the forecasted budget by 7.43% after 6 month updating. This was because the client's payment of additional fees for modification did not amount to 100%. This might have been on account of those client's installment of extra fees to change didn't measure on 100%. In addition, initially in every project it happens that the project will be behind schedule planning because of setting the resources i.e. machinery...etc. But this sliding in cost is recovered after taking precaution, the cost performance significantly became better compared to the previous status report and the project saved the estimated budget by 5.3%, lastly on the 14th month review the cost performance was better than the 6th month updating, but slightly worse than the last updating and the saving of estimated budget reduced to 3.6%.

For instances in the current project both the CPI / SPI on the 6th month updating were behind schedule planning and making losses or over budgeted, and on the 10th month updating the project was ahead of schedule and under budgeted which is significantly desirable status report period and best for the client, Again on the 14th month review there was a slight worse change in schedule planning of the project and lagged behind the schedule but under budgeted. The third updating indicates that if the project manager is not only concentrating on critical paths activities but also focusing on the activities which are interconnected with critical activities.

To illustrate the application of EVM method an instance problem is taken into account which works as a reliable tools on account of forecasting the total project cost as well as duration. Irrespective of pattern and frame of the project and with an accurate schedule plan and suitable tracking practice, this particular approach can be used as an early warning means to project teams, indicating that specific section of the project is not being done as per the planned schedule, therefore it avoids great deviation of cost sliding , time or scope.

Considering the present study's findings, future works can carry on to extend the EVM practice in procurement management. Basically, the investigation procedure of procurement departments is

terribly long, and materials cannot be kept for a long time, which postpones required schedule and wastes redundant resources of the company.

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